THE EFFECTS OF HERBICIDES IN SOUTH VIETNAM

PART B. WORKING PAPERS: AIR-PHOTO STUDIES OF THE RUNG-SAT

NATIONAL ACADEMY OF SCIENCES-NATIONAL RESEARCH COUNCIL

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Several of the questions posed by the Committee on the Effects of Herbicides in Vietnam regarding mangrove/herbicide relationships are conceivably amenable to air-photo study. These include the following. What were the composition and distribution of the mangrove communities prior to spraying? How sensitive are the mangroves to herbicide application; more specifically, how does damage vary with species, site, and number of times sprayed? What can we say about the rate, species composition, extent, and distribution of recovery and recolonization? What has been the rate, extent, and location of post-spray invasion by nonmangroves (shrubby and herbaceous species), and what is the effect of this invasion on reestablishment of mangroves? What are the extent and nature of accelerated erosion caused by the spraying? How extensive have been the salvage operations of woodcutters, and have they had detectable effects on regeneration and erosion? Some of these questions have been partly answered through the previous work of this Committee, and to a limited degree, in the literature. This report summarizes our efforts to supplement this information through the study of sequential aerial photography

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(1958 to January 1973) used in conjunction with observations and ground photographs made during the December 1972 visits to the Rung-Sat.

Much of this report deals with our analysis of sequential photography of Thanh-An Island. In addition, we have compared the January 1971, 1:5000-scale color photography of the Rung-Sat with the color photography of the same scale taken for the Committee in October 1972 and January 1973, wherever dual coverage was available in the Rung-Sat. This allowed the detection of smaller changes (e.g., recent regeneration) than would have been possible with smaller-scale photography, even though the interval was only about two years. Also, we made limited observations of areas elsewhere in the Rung-Sat when required in connection with specific questions--e.g., the role of Acrostichum, differential erosion between sprayed and unsprayed areas. We intend to conduct additional sequential studies of the vicinities of the Drew-Ho sites[a] and the new site (KKW site at YS044702) visited on December 16, 1972.

Our observations, soil samples, and ground photographs in the field were made with the subsequent study of the air photos specifically in mind. Accordingly, the locations of these activities were chosen to represent the range of air-photo patterns found in the general areas that were visited, and each location was marked carefully on the air photo. This allowed us later to extrapolate these field data on a pattern basis. Using sequential photography, we then could attempt to reconstruct the pre-spray vegetation communities and trace the response of these communities to the

[a]For location of the Drew-Ho sites mentioned throughout this report, see sites 2 and 7 in Figure IV C-5, Part A of the Report of the Effects of Herbicides in South Vietnam.

spraying.

As a supplement to this report, we provided the Committee with a 1973 aerial photograph of lower Thanh-An Island and an overlay showing our reconstruction of the pre-spray vegetation types; aerial and ground photographic documentation is available where appropriate to support any portions of this study to be incorporated into the final report.[a]

DISTRIBUTION OF PRE-SPRAY MANGROVE COMMUNITIES ON THANH-AN ISLAND

In trying to reconstruct the vegetation of Thanh-An Island, we began by reviewing field notes and ground photos to determine species composition (from living plants or identifiable remains) at known locations. We extrapolated these data elsewhere on the basis of (1) air-photo patterns; (2) known site preferences of genera obtained from Committee members, the air photos themselves, and the literature; and (3) known herbicide sensitivities, used in conjunction with the sequential photography. The different sets of photography comprising the sequential coverage were useful in delineating type boundaries, since for various reasons certain sets emphasized certain vegetation types more than others. In the discussion that follows, only those genera for which specific field evidence was found are mentioned. Undoubtedly, therefore, some genera occurring in the pre-spray condition are excluded. We feel, however, that the major components of the various types are considered.

It is well known that elevation and the associated frequency and duration of tidal inundation are of major importance in the distribution of the mangrove types. Thus, relative elevation (quantitative elevation

[a]These materials are in the office files of the NAS/NRC Committee on the Effects of Herbicides in Vietnam.

data are not available for Thanh-An Island) is the significant independent variable in the generalized profile of reconstructed vegetation types shown in Figure 1 and in the remainder of the discussion in this section.

The "foot" of Thanh-An Island (a WNW-ESE belt $1\frac{1}{2}$ to 2 km across the southern end of the island) appears to be composed of more recent alluvium and to have a lower average elevation than the rest of the island. This observation is supported by its greater drainage density, higher percentage of inundation at high tides, change in vegetation to a distinctive dark-toned type (pre-spray), and apparently continuing active accretion. Numerous large trees occurred along and near the stream banks in this "foot." Observations of the stump remnants of some of these trees near Teas site 2[a] indicated that they were Sonneratia. From the similarity of photo pattern and site (fresher alluvium more favorable to Sonneratia?) and the fact that sequential photography shows these trees to be killed by a single spray application (Sonneratia considered one of the more sensitive genera), we conclude that most of the large stream-bank trees in the "foot" and in other low areas on the island were also Sonneratia. Other stream-bank trees, generally smaller and perhaps occurring somewhat higher on the banks than the Sonneratia, were not killed by a single spray, and many of these are still living. We are confident that most of these are Avicennia, and have based this conclusion on direct observation in the field and extrapolation to other locations

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[a]For location of the Teas sites mentioned throughout this report, see site 4 in Figure IV C-5, Part A of the Report on the Effects of Herbicides in South Vietnam.

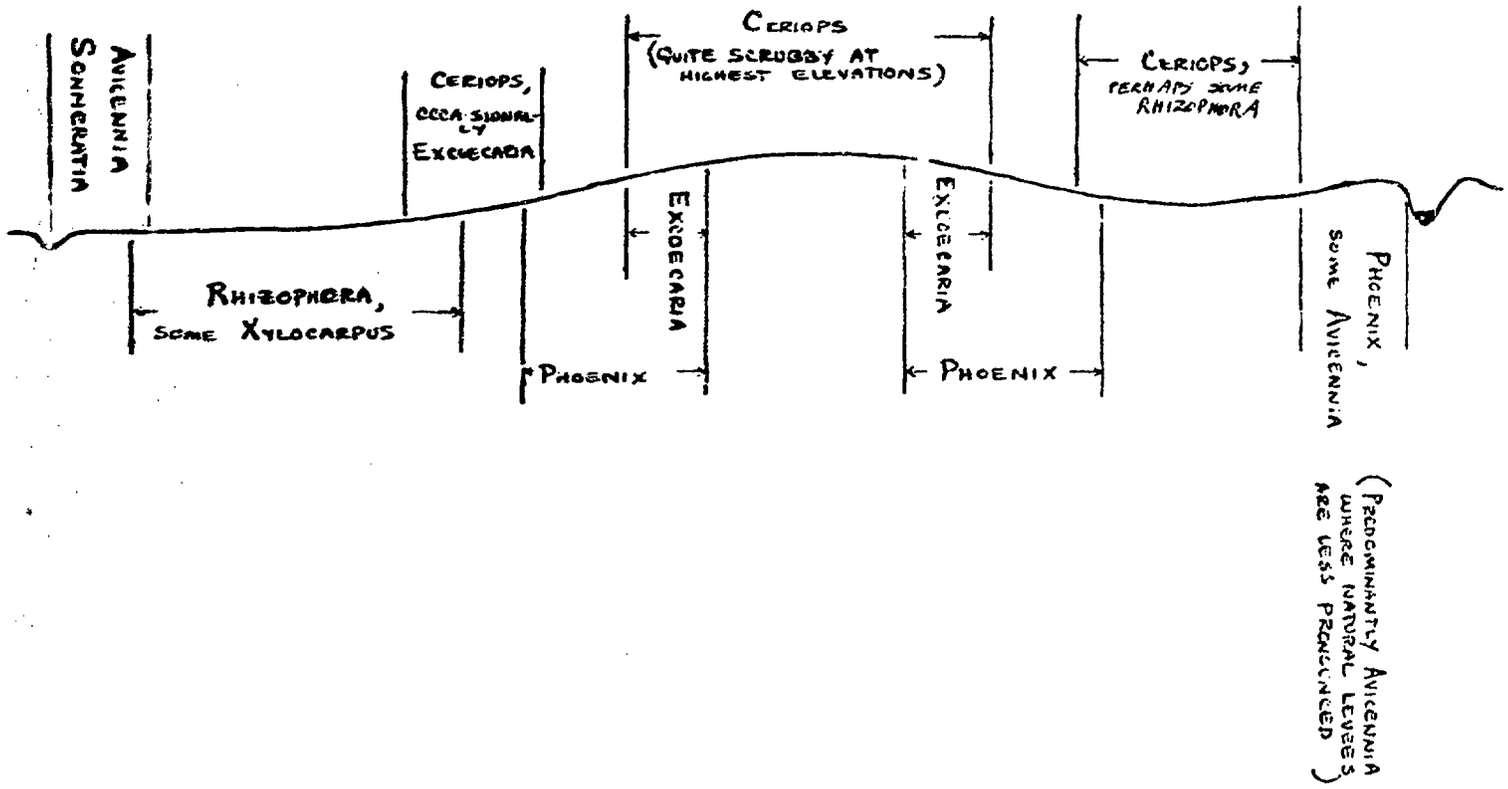


FIG. 1. Typical cross section of Thanh An Island.

using the similarity of photo pattern to that of known Avicennia trees, as well as on their apparently greater resistance to spray. In parts of the island where average stream-bank elevations are higher, the evidence suggests an increase in the ratio of Avicennia to Sonneratia.

Most of the finer-textured, dark-toned trees in the Thanh-An "foot" were probably Rhizophora. This pattern could be correlated with dense Rhizophora remains in some locations, particularly at Teas site 2. The pattern also is similar to that of Rhizophora observed elsewhere. The site characteristics--low to medium elevations, frequent flushing by the tides, relatively fresh alluvium--are consistent with the occurrence of Rhizophora. Furthermore, these trees were killed by a single spray, again compatible with a Rhizophora interpretation. In the field we found Xylocarpus remains in with the Rhizophora remains, suggesting an association of these two genera (also indicated in Vu-Van-Cuong 1964). Other genera also are probably associated with Rhizophora in this area, but we found no specific ground evidence of them.

The Rhizophora type extends from the Sonneratia-Avicennia of the bank margins across the frequently-inundated tidal flats and onto the lower slopes of the older, higher alluvium. Here it begins to become mixed with Ceriops and occasionally with some Excoecaria. A little higher the Rhizophora stops and a relatively narrow band of almost pure Ceriops is found. The identity of the Ceriops and Excoecaria in this zone was verified by field inspection. The apparent tolerance of these two genera to at least one spray application (discussed later) helps in distinguishing them from Rhizophora. This persistence after one spray also indicates that Ceriops is probably more abundant than Rhizophora in some of the higher tidal flat

areas found north of the "foot" on Thanh-An Island.

The Ceriops band gives way at higher elevations to a zone of practically pure Phoenix. The Phoenix type usually has rather sharp boundaries, perhaps suggesting relatively narrow tolerance limits with respect to elevation. This zone has a very characteristic air-photo pattern: on panchromatic photos it displays the lightest tone of any of the mangrove types (a distinctive gray-green on color photos) and, as suggested earlier, typically occurs within fairly distinct boundaries. Even areas in which Phoenix has been destroyed have a distinctive pock-marked air-photo pattern. Mature stands of Phoenix often have completely closed canopies. Where the canopy is more open, however, as may be the case along the stand boundaries, a dense understory of Ceriops commonly develops; Excoecaria may be mixed in as well, usually along the upper margin of the Phoenix.

To a lesser extent, Phoenix also is found to be fairly dense along the banks of a minority of the streams of Thanh-An Island. These tend to be the streams that are relatively deeply incised into the higher areas and that may have significant natural levees along their margins, as contrasted with those occurring in lower areas, whose banks have less relief and whose headwaters diverge into broad, shallow fans. The banks of the former type of streams evidently are high enough to support Phoenix. Once established, the palms appear to accumulate soil around their bases, thereby further elevating and improving their site.

Above the Phoenix zone the dominant genus is Ceriops. Extensive areas of high, dry ground on Thanh-An Island, particularly inland from Teas si'es 3, 4, and 5, were occupied by dense Ceriops thickets. Ceriops

appears to remain dominant up to the highest sites, where it becomes somewhat sparser and shorter. Excoecaria frequently occurs fairly densely along with Ceriops in a band just above the Phoenix zone, and then becomes less abundant at the higher elevations. Both Ceriops and Excoecaria decrease in height with increasing elevation. In some areas one or both of the Phoenix and Ceriops-Excoecaria bands may be missing; in the latter case a continuity between the lower and upper Ceriops types results. Evidently Ceriops tolerates a wide range of conditions. Perhaps these lower and upper Ceriops types represent two different species (C. tagal and C. decandra), a possibility that we unfortunately did not check in the field.

HERBICIDE SENSITIVITIES AND RECOVERY OF MANGROVES

The use of variously-dated photography was of particular importance in this part of the study. Specific trees and groups of trees were followed through the sequence of sprayings to try to determine the dosage required for damage/recovery and that for complete kill. Reconstruction of the exact sequence of herbicide applications in this heavily-sprayed area was not particularly straightforward; nevertheless, we feel something useful can be said about herbicide sensitivities.

It was stated earlier that both Sonneratia and Rhizophora were killed by a single spray application. In fact, this observation was used to some extent as a diagnostic tool for identifying these genera. (A bit of circular reasoning may be involved here, but taken with other evidence regarding the identity and herbicide sensitivity of these genera, we feel our conclusions are sound.) To our knowledge, no survivors of Sonneratia

or Rhizophora were observed on Thanh-An Island.

Based on our air-photo studies, we concur with the view that Avicennia is the most herbicide-resistant of the mangroves in this area. Several Avicennia survived the multiple spraying (at least two doses, probably more) on the west coast of Thanh-An Island. The percentage of survivors is difficult to estimate, since Avicennia trees are not sufficiently distinctive on the pre-spray panchromatic photographs to permit their reliable identification. It should be noted that most of the Avicennia survivors were among the smaller of the large stream-bank trees. Whether this means that the smaller (younger?) Avicennia individuals for some reason were more resistant or that the larger trees were not Avicennia (Sonneratia perhaps?), we do not know. Another observation regarding Avicennia survival is in order. It has been suggested that the survival of Avicennia is enhanced by proximity to streams. This is a reasonable assumption given the fact that the great majority of Avicennia survivors are in fact found near streams. However, careful study of the photos has led us to conclude that this is the case simply because these are the sites occupied by Avicennia to begin with; i.e., the average proximity to stream of these survivors does not appear to be significantly different from that of the large stream-bank trees (including Avicennia) in the pre-spray condition.

Phoenix appears to suffer substantial damage, including destruction of much of the upper crown, from one spray, but the survival rate is high. The pattern and rate of regrowth shows almost certainly that this is recovery of damaged individuals rather than recolonization by new seedlings. The great majority of the Phoenix on Thanh-An Island, and probably through-

out the sprayed portion of the Rung-Sat, appears to be survivors rather than new regeneration. A second dose, on the other hand, evidently causes heavy mortality. The result is pronounced linear edges of surviving Phoenix stands in several areas, corresponding to the boundary between one and two spray applications. By contrast, these edges are rarely seen with Avicennia, presumably because of its greater herbicide resistance and because on Thanh-An Island it normally does not occur in in extensive, continuous stands in the pre-spray condition.

We obtained some limited evidence that Phoenix survival may be better on stream-bank sites (described earlier) than on the medium elevation inland sites. Phoenix stands on two such sites were studied. All trees were killed back essentially to the ground by a second spray application. The inland group died, while the stream-bank stand recovered (slightly more favorable site?)

A related observation concerning survival of Phoenix seedlings was made in the vicinity of Teas site 6. An extensive, dense zone of Phoenix occupied the medium elevation areas near this site prior to spraying. The multiple spraying along the west coast of the island completely destroyed this zone, as might be expected, and no visible regeneration has become established here. However, today there are a number of young Phoenix plants at the lower elevations nearer the stream. Oddly enough, very few if any mature Phoenix individuals could be found in this latter area on the pre-spray photography. These young Phoenix are visible as very small plants on 1966 photography (after most of the overstory trees had been killed), so they probably were already established as seedlings when spraying commenced. Perhaps they survived because of shielding from

spray by the overstory canopy, or maybe the seedlings for some reason have a greater natural resistance to herbicide than the mature palms. But one also would expect seedling establishment, presumably in much greater numbers, within the main Phoenix zone. Why, then, are there no young Phoenix survivors there? Perhaps the lower site was significantly more favorable for seedling survival after the microenvironment-moderating influence of the overstory canopy had been removed. Maybe greater flushing of herbicide by the tides in the lower area was a factor.

On the basis of these observations, it may be postulated that proximity to streams (or perhaps simply elevation) is a significant factor in Phoenix survival and recovery, even though it does not appear to be applicable in the case of Avicennia.

Ceriops and Excoecaria seem to have roughly the same sensitivity range as Phoenix, i.e., they survive on one dose (with the exception noted below), but are usually killed by a second or third application. The pronounced spray-related lineations mentioned earlier in the case of Phoenix are common also for Ceriops and Excoecaria. Where Ceriops occurs as an understory of incompletely closed Phoenix canopies, survival may be extended because of partial overhead shelter from the herbicide. As indicated for Phoenix, practically all the Ceriops and Excoecaria trees visible on current air photos are almost certainly survivors rather than new seedlings, despite the small stature of much of the Ceriops (1.0-1.5 m). The growth form of these trees is not typical of recent seedlings, and few--if any--new, living seedlings were observed adjacent to surviving stands on the higher inland sites. Furthermore, the continuous existence of these stands could be followed on the sequential photography.

A notable exception to the survival of one spray application by Ceriops is found on the highest sites on Thanh-An Island. Here the trees are sparser and somewhat shorter, and one spray produces virtually complete kill. Thus, after one spray, denuded summit areas appear as islands within otherwise vegetated terrain. Apparently these sites are so marginal for normal survival and growth of Ceriops that the trees cannot tolerate the additional stress of herbicide application. There is some evidence of preferential pre-spray harvesting of trees on these highest sites (perhaps denser wood better for charcoal?), but the extent and rapidity of destruction in these areas following spraying indicates that woodcutters are not the major factor in this situation.

MANGROVE RECOLONIZATION

In general, the air photos have not proved very useful in studying recolonization. Most of the seedlings are too small to be resolved on our 1:5000-scale photography. The poor resolution of the new Committee photography (October 1972 and January 1973) presents particular difficulties in this regard. To emphasize the appearance of any new vegetation, we compared large-scale (1:5000) color photography taken in January 1971 and October 1972/January 1973 over the areas in the Rung-Sat covered by both sets. A greater time span probably would have been preferable, but was not available at this scale. Of all the locations checked, only one area--portions of the east bank of the Song-Dong-Tranh north of Dong-Hoa--showed unmistakable signs of new tree seedlings over this two-year interval. These seedlings occurred on fresh mud banks, evidently a quite favorable site for rapid colonization and growth of pioneer species. (This may support the idea,

incidently, that site quality differences--e.g., freshness of alluvium, elevation--as well as seed supply are quite important in the observed differences in rate of recolonization between the Rung-Sat and the Ca-Mau.) Very marginal indications of an increase in "green stuff" on a few stream levees were the only other possible air-photo evidence of mangrove recolonization during this interval. Many very small trees could be seen, but these were invariably visible two years earlier, and tracing them back further on small-scale panchromatic photos generally was not feasible. We searched for new seedlings within and along the margins of surviving stands or clumps of trees (including Avicennia, Phoenix, Ceriops, Excoecaria), and always found that, while height and crown size of individual trees might increase to some extent over two years, no new trees could be seen.

The general location and composition of mangrove reproduction observed on the ground has been noted by others in the course of the Committee's study, so it is not necessary to discuss that here.[a]

DISTRIBUTION AND COLONIZATION OF SHRUBBY AND HERBACEOUS SPECIES

The nonmangrove of greatest interest to the Committee has been the fern Acrostichum. We hope to do more detailed studies of the fern in the course of sequential analyses of the Drew-Ho sites and the new (KKW) site. However, we have made some preliminary air-photo observations.

Acrostichum presently occurs on somewhat elevated sites in the

[a]See Ross, P. The effects of herbicides on the mangrove of South Vietnam, Part B of the Report on the Effects of Herbicides in South Vietnam.

middle and upper Rung-Sat. It is found both on natural levees and in the upper elevations of interior areas. From a preliminary attempt to reconstruct the role of Acrostichum in the pre-spray mangrove, it appears that the fern normally occupies an understory position. In the inland sites, it is associated closely with former or remnant Phoenix. The present boundaries of these inland Acrostichum stands correspond remarkably well with those of earlier Phoenix stands as observed on pre-spray photographs. This postulated understory position is supported by the partial destruction by spraying of the Phoenix canopy in some places, thereby revealing a dense lower stratum of Acrostichum immediately adjacent to the remnant edge. Also, Acrostichum often can be seen through incompletely closed Phoenix canopies. Where the fern occurs on levees along streams, its overstory appears to have been more variable--sometimes Phoenix, sometime other species as yet unidentified.

The boundaries of Acrostichum stands typically are fairly sharp and often closely related to elevation contours, perhaps reflecting critical lower elevational limits. Evidently its upper elevational limits are higher than those of Phoenix, since in a few cases Acrostichum appears to have occurred without an overstory in summit areas above the Phoenix zone. This is somewhat reminiscent of the position of Ceriops in the more saline lower Rung-Sat. There is some evidence that uncovered Acrostichum may have occupied part of the very dry, high portion of the KKW site near Drew-Ho site 1. This is an area which, once denuded, may become hostile to any natural recolonization for a considerable time.

Post-spray Acrostichum stands are often nearly pure. Sometimes, however, the fern is mixed with a few Phoenix palms or other trees, and

sometimes it adjoins or associates with species such as Azima, Wedelia, and Pluchea. A few kilometers south of Drew-Ho site 1, the range of Acrostichum overlaps with that of Ceriops. Currently these two occupy quite similar sites in this region, often growing side by side, except that Ceriops is seldom found along stream banks. Acrostichum was observed sometimes as an understory of Ceriops, which in turn occasionally grew beneath an open Phoenix canopy. There appear to be many interesting relationships here which time has not allowed us to pursue.

Acrostichum on Thanh-An Island is very limited. We found only scattered individuals around the bases of a few elevated ridges (remnants of old forts or kilns?).

Evidence of Acrostichum regeneration was sought on the two sets of color photography along with that of tree regeneration. In most cases, a small increase in height and crown size of individuals or clumps was the extent of the detectable change over the two-year interval. However, at a few locations, some newly visible individuals or clumps of the fern were observed. In every case (except as noted below), though, one got the impression of a "filling in" of an already-existing stand (probably there prior to spraying) rather than an extension of the boundary of the stand. In one instance, Acrostichum coverage increased substantially in two years, apparently invading a new area. But a closer look showed that the extent of the "new" stand was neatly defined by the boundary of an earlier Phoenix stand. This, together with the rapid rate of "invasion," suggests that after the Phoenix overstory had been removed, the Acrostichum was further sprayed enough to destroy the tops of the plants, then later resprouted from the surviving bases. In any event, our air-photo study

corroborates ground observations by the Committee that Acrostichum is not rapidly invading vast areas of denuded land.

Since we have not yet conducted detailed sequential studies in areas occupied by the fern, we cannot say much about its apparent herbicide sensitivity. It does persist, however, in river-bank zones sprayed at least twice. Because of its original understory status, it was probably little damaged by a first herbicide application. There is some evidence that it was damaged more in the higher summit areas, a situation similar to that of Ceriops on Thanh-An Island. In some cases this may have been due to the fern's uncovered position on some of these sites in the pre-spray forest.

Similarly, we can say little about the role of Acrostichum in mangrove succession. It does appear, however, that because it grows only on higher sites, the fern should not interfere with (or aid) recolonization by lower elevation mangroves such as Rhizophora.

The Azima/Wedelia/Pluchea association is almost entirely restricted to elevated stream banks. It does not normally occur on inland sites of comparable elevation. On Thanh-An Island, however, a few small patches of Azima and Wedelia were observed on the high, apparently artificial ridges to which we referred earlier. We have not looked at this association enough to be able to say anything about its probable role in the pre-spray forest. With respect to herbicide sensitivity, we can only say that, like Acrostichum, it does persist in zones that have been sprayed at least twice. We have not seen any air-photo evidence of colonization by new plants or clumps of Azima or Wedelia since January 1971.

Paspalum and other grasses and sedges also tend to favor stream-bank

sites, although they occupy substantially broader zones than Azima and Wedelia. Paspalum patches are rather limited on Thanh-An Island. In the middle Rung-Sat they become more extensive, and in the upper Rung-Sat herbaceous vegetation has covered a large portion of the bare soil areas. Paspalum appears to have lower elevational limits that may restrict its invasion into the extensive depressed areas around the headwaters of streams. In addition, its invasion of high, dry areas undoubtedly will be slow. However, there is air-photo evidence of considerable colonization by Paspalum on favorable sites in the middle Rung-Sat since January 1971. Effects of Paspalum on mangrove succession (filtering of seedlings, etc.) probably can be evaluated better on the ground than from air photos at this stage, and such observations have been summarized by others.

EFFECTS OF WOODCUTTERS

In most areas of the Rung-Sat that we have observed on air photos, salvage of dead trees has been quite complete. In a few locations, however, notably along the Song-Dong-Tranh, extensive areas of standing dead trees still exist. Perhaps this is owing to poor security. We did note that much of the debris (other than standing trees) evident on the January 1971 photography has since been removed, either by woodcutters or the tides. We have no basis for remarking on possible effects of salvage activities on either regeneration or erosion.

SOIL RELATIONSHIPS

Small-sized soil samples were taken in the lower and middle Rung-Sat as an activity of secondary importance. Because we had little time

in the field, primary attention was given to identifying vegetation species and locating them on air photos. Consequently, an insufficient number of samples was available for a statistically sound study or for more than a rough idea of relationships. Soils were given engineering tests for specific gravity, grain size distribution by hydrometer analysis, and Atterberg Limits. These were performed on baked specimens. Summaries of the results of these tests are shown in Figures 2 through 5.

Oven drying at port of entry into the United States affected the results so that liquid limits and plasticity indices have been lowered appreciably, especially the plasticity indices. Specific gravities were generally low (around 2.2), and this caused grain size curves to shift upward toward a finer grain distribution. All samples were treated equally, however, and relative relationships should still be intact. Plasticity indices ranged from 4 to 22 and liquid limits ranged from 48 to 82.

On the basis of the Unified Soil Classification System, all of the samples are classified as OH, organic clay and silt of medium to high plasticity, meaning they are plastic over a wide range of moisture contents. They are highly compressible and they are practically impervious.

The sites having the highest sand content and being the most coarse-grained are along the shore of Thanh-An Island, closest to the sea. Marine deposition of silt and sand appears to be present on the seaward portion of the Rung-Sat.

Distribution of soils in this river delta environment is random. The flowing water sorted particles by size, but deposition was random as stream courses meandered from side to side and channels were cut off and

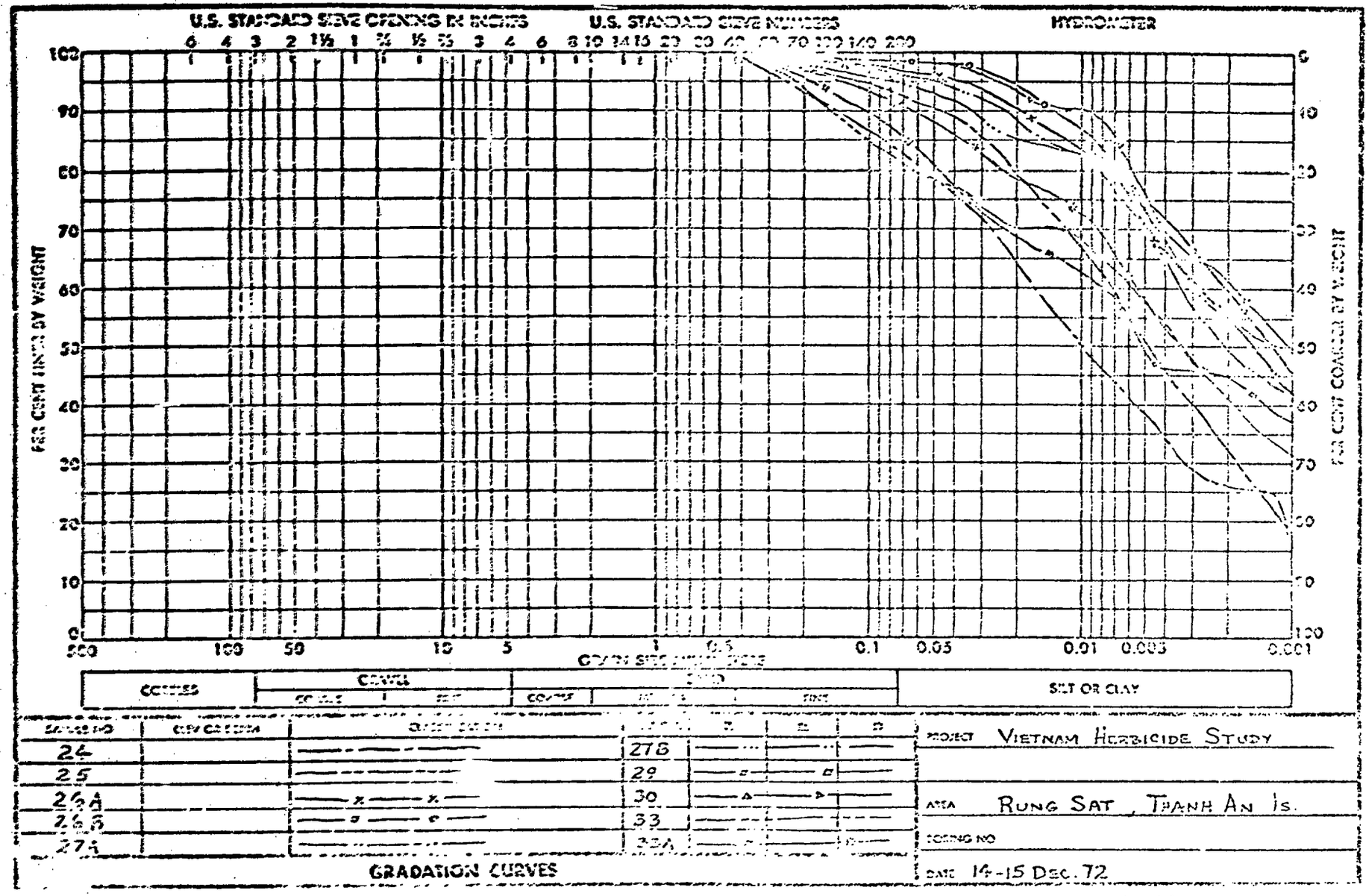


FIG. 2. Hydrometer analysis of soils from Thanh-An Island showing grain size distribution.

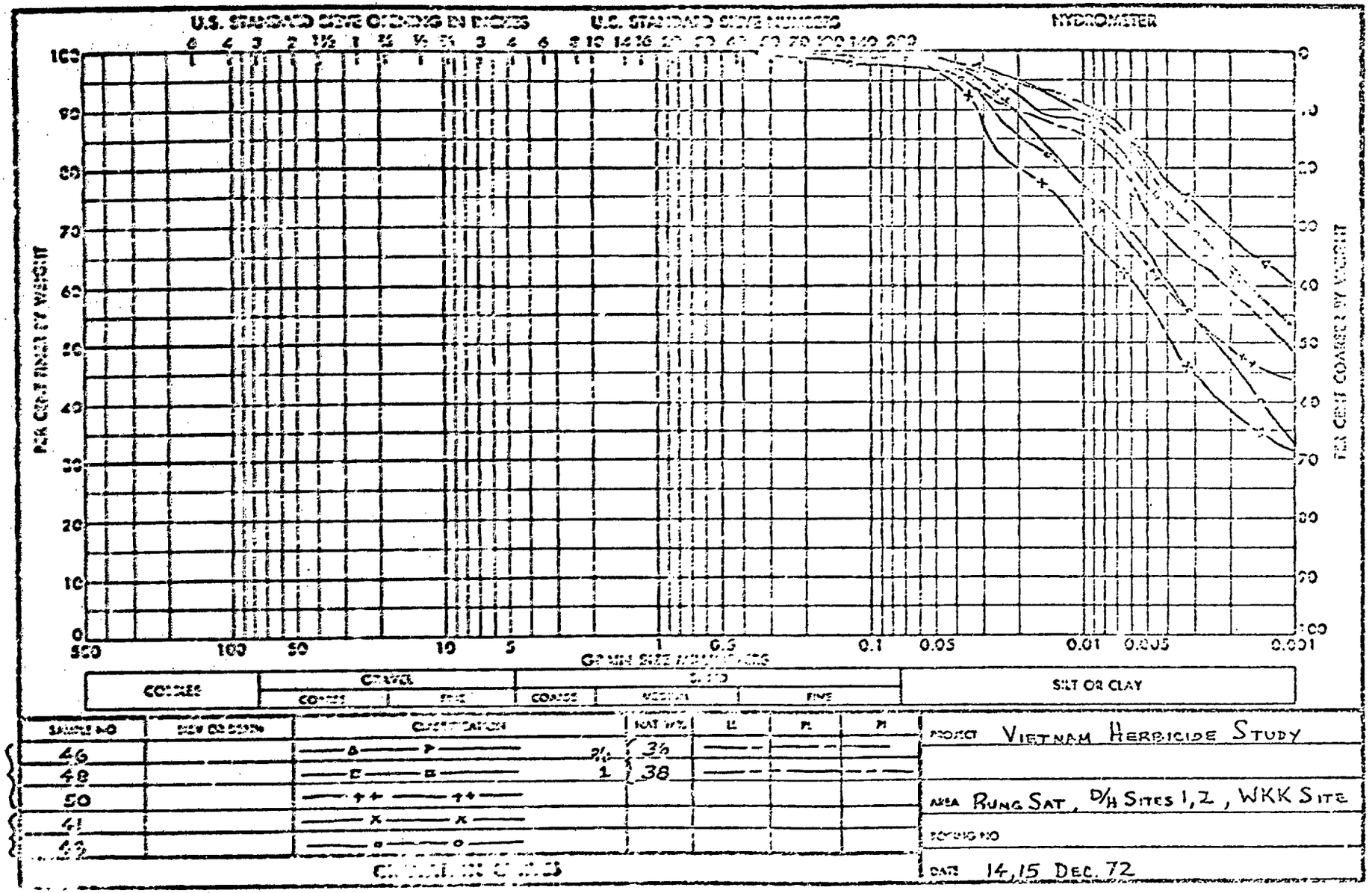


FIG. 3. Hydrometer analysis of soils from selected sites in the Rung-Sat showing grain size distribution.

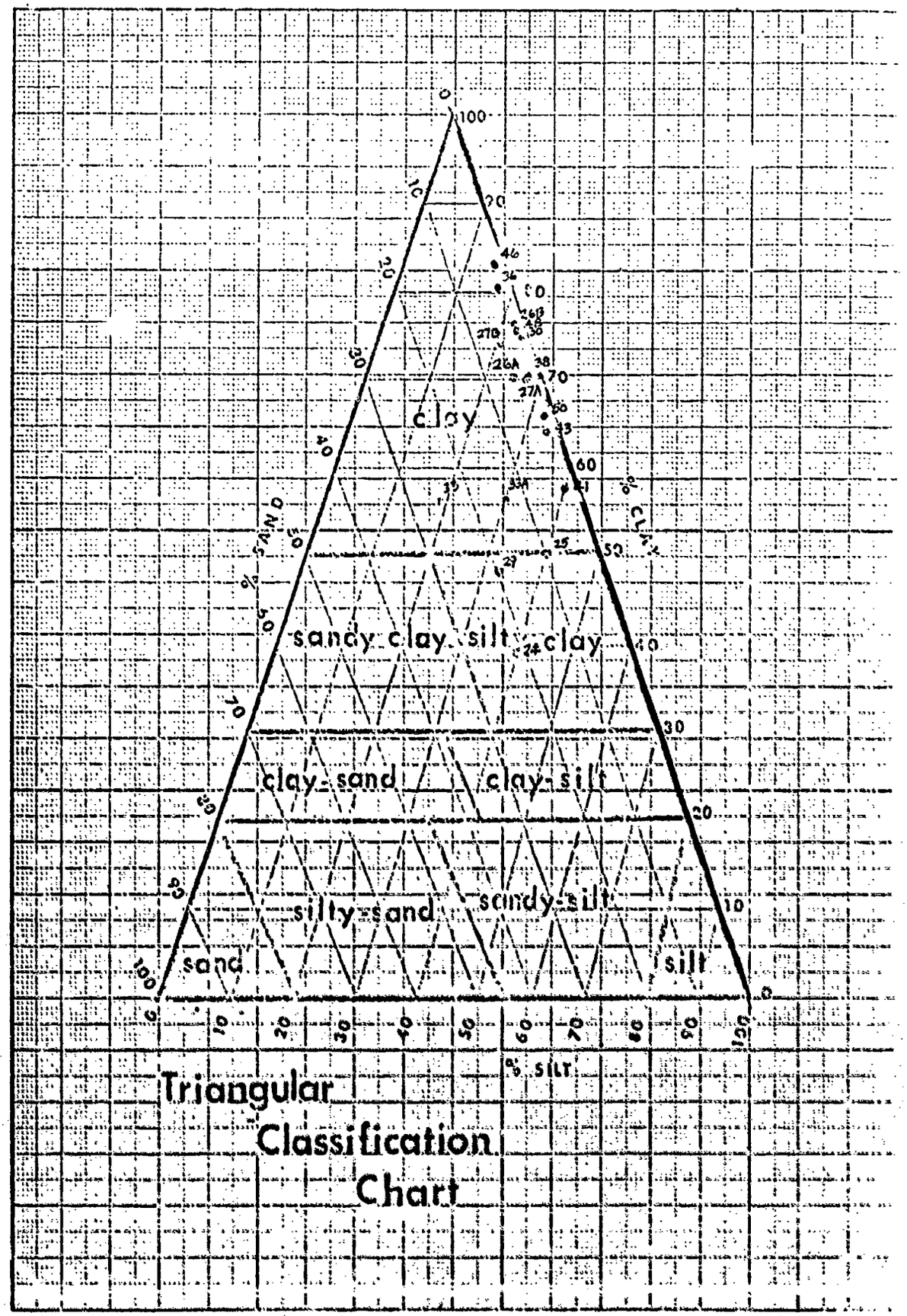
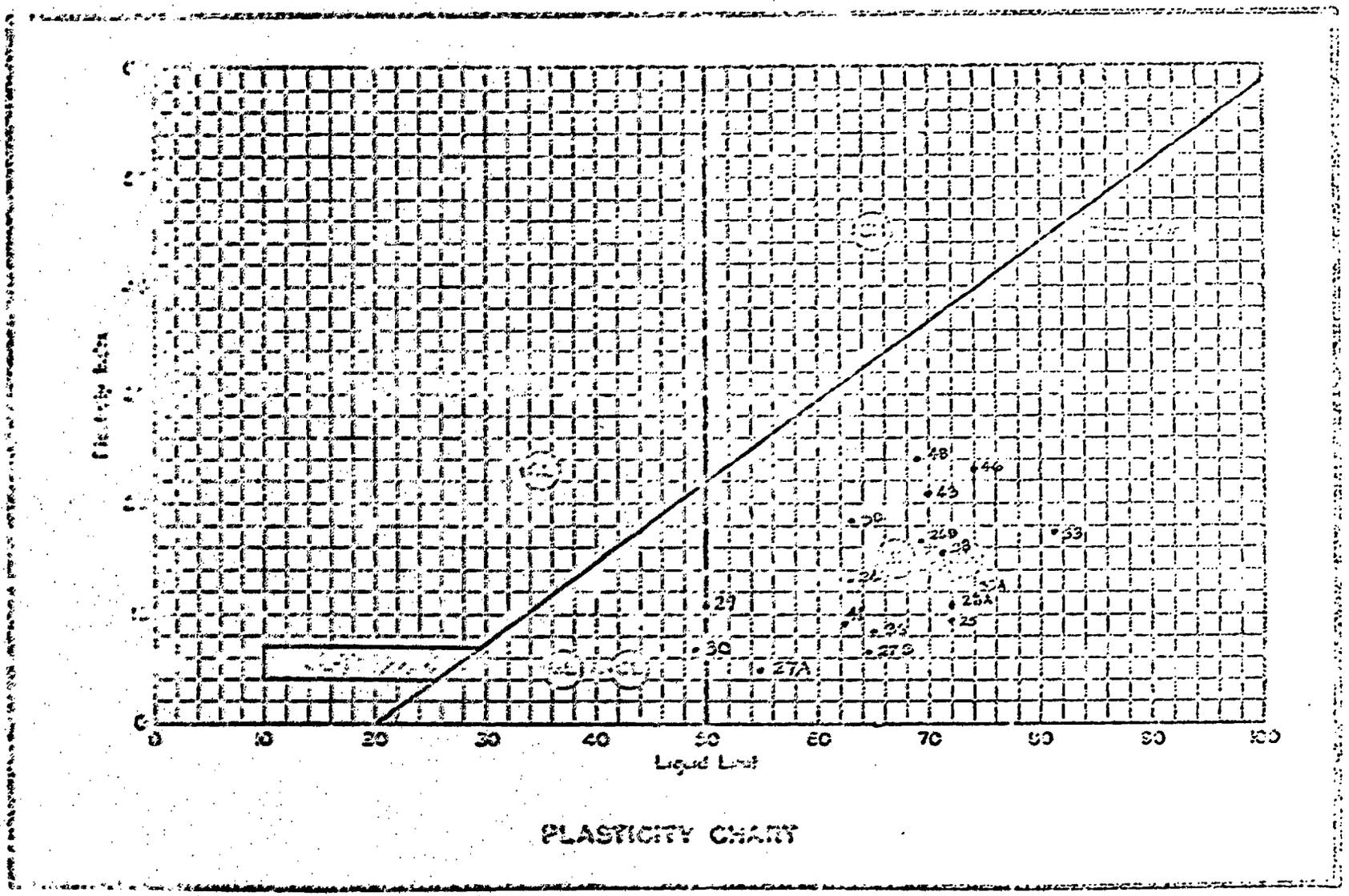


FIG. 4. Grain distribution size of soils in the Rung-Sat as shown by triangular classification chart.



PLASTICITY CHART

FIG. 5. Liquid limits and plasticity limits of soil from selected sites in the Rung-Sat.

changed. Thus, original soil profiles were different from place to place and bore little relation to present topography.

Data from two samples (46 and 27) indicated that the texture of the highest spots was relatively fine and may have resulted from the loss of the more erosive silt-size particles. Intermediate and lower elevations were both coarse-grained (more silt)--such as samples 24, 25, 29, and 33--and fine-grained (more clay)--such as samples 26, 36, 38, and 48. This indicates that the vegetation of the area is more dependent on topographic position or some other factor than on the soil properties tested for here, which were texture, plasticity, and compressibility.

EFFECTS OF SPRAYING ON SOIL EROSION

The question of the extent of accelerated soil erosion can be answered only in a general manner. The answers are based on ground observations of exposed roots and on spatial arrangements and tones of features on air photos. No direct measurement of erosion was possible on air photos, and shoreline comparisons could not be made because of the drastic change in the water/land boundary brought about by the tidal cycle, a vertical distance of about 3 m.

Ground observations on Thanh-An Island showed old cable root systems, which were once buried, now exposed about 4 in. on low inland tidal flats, and Ceriops stumps with the bottom sides of once-buried roots now elevated about 1 in. on high, dry, seldom-washed areas. Grass clumps were observed on columns about 4 in. above the surrounding bare soil. Phoenix stumps were characterized by ring-shaped mounds of soil, built up around the roots, that were obvious remnants of a previous soil level, held in place

by the Phoenix roots. These are the most positive evidences of accelerated erosion.

The extensive inland tidal flats at the headwaters of many streams have been cited as evidence of accelerated erosion caused by the spraying. In studying sequential photography, however, we have observed that these same tidal areas were present prior to spraying. They are less pronounced on the pre-spray photography simply because much of their upper reaches was covered with vegetation, which was mostly removed by spraying. In an attempt to assess any change in the size of these areas since spraying, we compared 1966 photography (in areas where the trees already had been destroyed by herbicide application) with coverage of later dates. It soon became apparent that tide level critically affects the apparent extent of the tidal flats, making rigorous evaluations of small changes virtually impossible. However, the general form and extent of these flats appear to have remained substantially unchanged. As indicated earlier, there has been some (probably accelerated) sheet erosion that has lowered the overall surface to some extent, but evidently there has been no remarkable increase in headward erosion of the inland tidal areas. This is supported by a few ground observations in such areas, in which the roots of tree stumps at the peripheries of the flats are exposed only slightly or not at all.

The magnitude of erosion undoubtedly varies with location as a function of several factors, including soil texture (more erosion occurs in areas with a higher proportion of silt, e.g., sample 25), elevation, distance inland (less erosion occurs in areas farther inland, e.g., sample 41), and the amount of remaining vegetation or vegetation remnants.

Another possible air-photo approach to the problem of erosion is the comparison of water turbidity in sprayed and unsprayed areas. The evidence is limited and not too consistent. Examination of recent small-scale color photography of the Rung-Sat does seem to show greater turbidity in the channels of the sprayed western portion of the Rung-Sat than in those of the unsprayed eastern portion. Of course, we have no way of making quantitative estimates of erosion differences from this information. In the Ca-Mau, on the other hand, no such differences were observed between sprayed and unsprayed areas. Here again, the tidal stage is probably quite important in affecting the usefulness of this technique.

REFERENCE

Vu-Van-Cuong-Humbert, F.S.C. 1964. Flore et vegetation de la mangrove de la region de Saigon-Cap Saint-Jacques, Sud Viet-Nam. Thesis, Univ. of Paris. 188 pp.